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Understanding some of Nutritional Characteristics of Twelve Cassava (Manihot esculenta Crantz) Genotypes in Southern Tanzania

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Abstract
Cassava (*Manihot esculenta* Crantz) roots are used as staple food. Dry matter (DM) content, crude protein content, starch content and root taste estimation and proximate composition were investigated in twelve cassava genotypes in 2011-2012 season. Root DM varied from 40.52% in NDL 2006/487 to 35.02% in NDL 2006/850. The genotype that showed highest starch percentage was NDL 2006/487 (23.10%) while the lowest value (19.20%) was observed from NDL 2006/850. Crude protein varied from 0.24% in Kiroba to 1.39% in NDL 2006/487. Also root taste varied considerably; genotype NDL 2006/741 being the sweetest with an average value of 1.06, while genotypes NDL 2006/487 and NDL 2006/850 had the bitterest taste both with an average value of 1.89. Hydrogen cyanide content estimation/extraction was not conducted in this study. Genetic variation for DM, starch, protein and root taste existed in twelve cassava accessions, and NDL 2006/487 may be a better genotype due to its higher DM% content, starch% content and comparatively high protein% content.
Keywords: Cassava roots, Dry matter, Starch, Protein, Root taste, Estimate

1.0 Introduction

The cassava (*Manihot esculenta* Crantz) is cultivated mainly in the tropic and sub-tropic regions of the world, over a wide range of environmental and soil conditions. It is tolerant of insect pests and diseases, and is very tolerant of drought and heat stress. The cassava is not a labour intensive crop and produces well on marginal soils. In many of the cassava growing regions of the world, however, the cassava does not achieve its yield potential, due primarily to disease and limited inputs such as fertiliser and irrigation (Siritunga and Sayre, 2004). Estimates of the Food and Agriculture Organisation of the United Nations (FAOSTAT, 2011) put world production of cassava at more than 230 million metric tonnes annually. The cassava is an important component in the diets of more than 800 million people around the world (FAO, 2007) and is the third largest carbohydrate food source within the tropical regions, after rice and corn (Ceballos *et al*., 2004). Cassava is referred to as a food security crop (Barratt *et al*., 2006), which can be left in the ground for extended periods of up to two years, until required. It is used mainly as a fresh food item, but is also processed into various food and non-food products, such as starch, flour, beverages, animal feeds, biofuels and textiles. There is much variation in the nutrient quality of the cassava root (Chaves *et al.*, 2005). In the tropical regions, cassava is the most important root crop and, as a source of energy, the calorific value of cassava is high, compared to most starchy crops (Okigbo, 1980). The starch content of the fresh cassava root is about 30%, and gives the highest yield of starch per unit area of any crop known (Tonukari, 2004). The protein content is extremely low, however, and ranges between 1-3% (Buitrago, 1990; Salcedo *et al*., 2010). The cassava root contains a number of mineral elements, in appreciable amounts, that are useful in the human diet. The root contains significant amounts of iron, phosphorus and calcium, and is relatively rich in vitamin C (Enidiok, *et al.,* 2008).

There are several thousand varieties of cassava and about 100 related wild species (Hershey *et al*.,1997), with hydrogen cyanide (HCN) contents of their roots ranging from 1-1550 parts per million (ppm) (Cardoso *et al*., 2005). Cassava plants are generally categorised as bitter or sweet, depending upon their cyanide content. The low-HCN, or sweet cassava, has less than 50 ppm of cyanogenic equivalents, while the high-HCN or bitter cassava has more than 100 ppm (Wilson and Dufour, 2002). According to Adepoju *et al*., (2010), the food value of cassava is greatly compromised by its toxic hydrogen cyanide content. The sweet cassava can be cooked and eaten as they are, while the bitter cassava needs to be processed before being consumed. A large amount of variation exists among the cassava leaf, stem and root characteristics. These characteristics, which include leaf morphology, stem colour, branching habit and storage root shape and colour, may influence cassava yield (Ntawuruhunga and Dixon, 2010). Other, not so obvious, characteristics include resistance to insect pests and diseases. A proper understanding of these variations in plant characteristics would assist the selection of cassava types with the desired traits. This, in turn, will contribute to improved crop establishment and increased yields.

Among the objectives of the root and tuber crops sub programme at Naliendele Agricultural Research

Institute are to identify high yielding and disease/pests free cassava varieties, to evaluate and preserve cassava germplasm and to provide good quality planting material for local farmers. However, very little documented information on the nutritional status of cassava varieties in Tanzania. With this present study, efforts are being made to evaluate existing varieties and new introductions for their yield potential under local conditions. Cassava production in Tanzania could be improved through the introduction of improved varieties and the adoption of improved agronomic practices. The objective of the present study was to evaluate nutritional status of some traits of twelve cassava genotypes, to examine them for quality and yield of their tuberous roots.

2.0 Materials and Methods

2.1 Study Area

The study was conducted in three locations of Southern Tanzania at Naliendele (Coastal low land plains), Mtopwa(Makonde plateau) and Nachingwea(Masasi-Nachinwea plains), during the 2011 – 2012 cropping season under rain fed conditions.Naliendele is located at 10^o 22'S and 40^o 10'E, 120m above sea level and receives mean annual rainfall of 950mm with monthly mean temperature of 27^oC and average relative humidity of 86%. Nachingwea is located at 10^o 20′S and 38^o46'E, 465 m above sea level has a mean annual rainfall of 850mm, mean monthly temperature of 25^oC and annual mean relative humidity of 78%. Mtopwa is located at 10^o 41'S and 39^o 23'E, 760m above sea level receives a mean annual rainfall of 1133mm with monthly mean temperature of 23^oC and mean relative humidity of 75%. All three sites experience a mono-modal type of rainfall.

2.2 Experimental Materials and Design

Twelve cassava genotypes obtained from Naliendele Agricultural Research Institute, Mtwara, Tanzania were evaluated in Southern Zone of Tanzania during 2011/2012 cropping season to examine their nutritional quality. The locations were: Naliendele, Mtopwa and Nachingwea. A Randomized Complete Block Design (RCBD) with three replications was used at each location. Plants were established at 1m x 1m spacing in $28m^2$ plots. Neither fertilizer nor herbicide was applied to the plants. Weeding was done when necessary. Plants were harvested nine months after planting. Four nutritional traits examined were; dry matter percentage, starch percentage, protein percentage and root taste.

2.3 Statistical Analysis

Analysis of variance (ANOVA) was done to assess the genotype effects and their interaction using statistical package Genstat version 14.

2.4 Determination/Estimation of Variables

2.4.1 Dry Matter (DM) Percentage Content Determination

Dry matter comprises all remains after removing water from a cassava fresh root. Estimation of DM content in cassava bases on the principle of a linear relationship between specific gravity with DM (Kawano *et al.,* 1987).

DM % = 158.3x – 142; where *x* stands for the Specific gravity of the cassava root sample

Procedures: Root samples weighing 2 – 3 kg were used. The samples were weighed in air (*Wa*) and then weighed in water (*Ww*). These weights were then used for computation of specific gravity

$$Specific\ Gravity = \frac{Wa}{Wa - Ww}$$

$$\%DM = 158.3\left(\frac{Wa}{Wa-Ww}\right) - 142$$

Where: Wa = Weight of root sample in air (kg)
Ww = Weight of root sample in water (kg)

2.4.2 Starch content determination

According to Kawano *et al.* (1987), determination of starch content in cassava takes the same principles as those of determining DM%. In estimating the starch%, the relationship used was:

$$Specific\ Gravity = \frac{Wa}{Wa-Ww}$$

$$\%Starch = 112.1\left(\frac{Wa}{Wa - Ww}\right) - 106.4$$

Where: Wa = Weight of root sample in air (kg)
Ww = Weight of root sample in water (kg)

2.4.3 Protein content determination

Protein content determination was carried out by *Kjeldalh* method as described by AOAC, (1995). Amount of Nitrogen (N) was determined from the ammonia, which was then used to calculate the actual protein content in the sample using the formula:

$$Crude\ Protein = \%N\ x\ Factor$$

$$\%N = \frac{[14.01\ x\ (Titre - Blank) x\ Conc\ HCl]}{5.00\ x\ 10}\ X\ 100$$

Where: N = Nitrogen, Conc HCl = Concentrated Hydrochloric acid and Factor = 6.25

3.0 Results and Discussion

3.1 Nutritional Quality Characteristics of the Studied Cassava Genotypes

Significant variations ($P < 0.05$) among genotypes were observed for protein, dry matter, starch and root taste. Across locations, genotype NDL 2006/487 outperformed all of the tested genotypes for all of the nutritional traits studied, viz; dry matter percentage content, starch percentage content, protein percentage content and the highest root taste score (Table 2). This indicates that, the genotype has an added advantage for high nutritional quality characteristics. Furthermore, the genotype (NDL 2006/487) can be grown in variable locations because of being stable for these characters (Table 1). Kundy *et al*., 2014, also noted that the genotype NDL 2006/487 was also stable across locations in other traits apart from nutritional ones. This genotype therefore could be of profound importance in cassava breeding activities.

Table 1: Means of genotypes for four characteristics at each site

Genotype	Site											
	Naliendele				Mtopwa				Nachingwea			
	DM%	Sta %	Pro%	Taste	DM%	Sta%	Pro%	Taste	DM%	Sta%	Pro%	Taste
Albert	35.43^{dcba}	19.49^{cb}	0.14^{fe}	1.00^{c}	39.23^{cba}	21.83^{cba}	0.62^{d}	1.00^{d}	35.76^{b}	19.72^{b}	0.17^{fe}	1.67^{ab}
Kiroba	37.15^{dcba}	20.70^{ba}	0.21^{ed}	1.50^{cba}	38.91^{cba}	21.56^{cba}	0.20^{fg}	1.00^{d}	38.23^{ab}	21.47^{ba}	0.27^{ed}	1.17^{b}
Naliendele	35.29^{dcb}	19.38^{cb}	0.30^{d}	1.67^{ba}	38.97^{cba}	22.83^{ba}	0.32^{f}	1.50^{bc}	37.92^{ab}	21.26^{ba}	0.32^{d}	1.17^{b}
NDL2006/030	34.64^{dc}	18.92^{cb}	0.10^{f}	1.167^{cb}	36.29^{dcb}	19.47^{dc}	0.13^{g}	1.00^{d}	35.77^{b}	19.73^{b}	0.13^{fe}	1.17^{b}
NDL 2006/104	38.63^{ba}	21.09^{ba}	0.80^{c}	1.17^{cb}	38.36^{cba}	21.56^{cba}	0.91^{c}	1.00^{d}	39.05^{ab}	22.06^{ba}	0.92^{c}	1.67^{ab}
NDL 2006/283	37.17^{dcba}	20.72^{ba}	1.01^{b}	1.00^{c}	37.33^{dcba}	20.84^{dcba}	1.10^{e}	1.67^{cba}	40.95^{a}	23.40^{a}	1.26^{ba}	2.00^{a}
NDL 2006/438	37.61^{cba}	21.03^{ba}	0.98^{b}	1.50^{cba}	38.42^{cba}	21.61^{cba}	1.23^{e}	1.83^{ab}	38.53^{ab}	21.68^{ba}	1.17^{b}	1.17^{b}
NDL 2006/487	39.16^{a}	22.13^{a}	1.13^{a}	2.00^{a}	40.62^{a}	23.17^{a}	1.63^{a}	2.00^{a}	41.78^{a}	23.99^{a}	1.41^{a}	1.67^{ab}
NDL 2006/738	36.68^{dcba}	20.37^{cba}	1.13^{a}	1.83^{a}	36.90^{dcba}	20.53^{dcba}	1.47^{ba}	1.33^{cd}	36.02^{b}	19.91^{b}	1.18^{b}	2.00^{a}
NDL 2006/741	39.12^{ba}	22.10^{a}	0.07^{f}	1.00^{c}	40.11^{ba}	22.80^{ba}	0.09^{g}	1.00^{d}	40.41^{a}	23.02^{a}	0.08^{f}	1.17^{b}
NDL 2006/840	36.56^{dcba}	20.28^{cba}	1.13^{a}	1.67^{ba}	33.68^{d}	18.24^{d}	1.29^{eb}	1.83^{ab}	38.95^{ab}	21.98^{ba}	1.23^{ba}	2.00^{a}
NDL 2006/850	33.54^{d}	18.14^{c}	1.05^{ba}	1.83^{a}	36.21^{dc}	20.04^{dcba}	1.49^{a}	2.00^{a}	35.32^{b}	19.41^{b}	1.17^{b}	1.83^{ab}
Mean	**36.75**	**20.36**	**0.67**	**1.44**	**37.92**	**21.21**	**0.88**	**1.43**	**38.22**	**21.47**	**0.78**	**1.56**
s.e	2.84	1.91	0.08	0.4	2.85	2.07	0.16	0.32	3	2.13	0.16	0.29
c.v. (%)	7.7	9.4	12.3	27.8	7.5	9.8	17.7	22.2	7.9	9.9	21.2	18.6

Where: DM = Dry matter, Sta = Starch, Pro = Protein

Table 2: Combined means of genotypes for four cassava nutritional variables at the three sites

Genotype	Dry matter%	Starch%	Protein%	Root taste
ALBERT	36.81^{cdef}	20.35^{cd}	0.30^{e}	1.22^{ef}
KIROBA	38.10^{bcd}	21.25^{bc}	0.24^{e}	1.22^{def}
NALIENDELE	37.39^{cde}	21.16^{bc}	0.31^{e}	1.44^{cde}
NDL 2006/030	35.57^{ef}	19.37^{d}	0.12^{f}	1.11^{f}
NDL 2006/104	38.68^{abc}	21.57^{bc}	0.88^{d}	1.28^{def}
NDL 2006/283	38.49^{abcd}	21.65^{bc}	1.12^{c}	1.56^{bc}
NDL 2006/438	38.19^{bcd}	21.44^{bc}	1.13^{c}	1.50^{bcd}
NDL 2006/487	40.52^{a}	23.10^{a}	1.39^{a}	1.89^{a}
NDL 2006/738	36.53^{cdef}	20.27^{cd}	1.26^{b}	1.72^{ab}
NDL 2006/741	39.88^{ab}	22.64^{ab}	0.08^{f}	1.06^{f}
NDL 2006/840	36.39^{def}	20.17^{cd}	1.23^{b}	1.83^{a}
NDL 2006/850	35.02^{f}	19.20^{d}	1.23^{b}	1.89^{a}
Overall mean	**37.63**	**21.01**	**0.77**	**1.48**
s.e	2.91	2.05	0.13	0.38
c.v. (%)	7.70	9.80	17.20	25.70

Means with the same superscript letter(s) in the same column are not significantly different ($P \leq 0.05$) following separation by Duncan's Multiple Range Test.

Key: Scale used for root taste: 1 – 2; where; 1 = sweet and 2 = bitter.

3.1.1 Dry matter percentage

Based on the results of this study, it was observed that the mean dry matter percentage varied significantly within and across locations. Percentage dry matter content in genotypes ranged from 35.02 to 40.52 %. This is in range with the results from the experiment done by Perez, *et al.* (2001) where the dry matter content ranged between 10.72 and 57.23%. In one site of the study, dry matter percentage had relatively higher means compared to other sites. This could be contributed by the amount of rainfall received in that location during 2011 – 2012 cropping season, which was higher compared to other sites. This suggests that the root dry matter yield decreases under low water conditions. This is in agreement with Schulthess *et al. (*1991) who observed that the effect of drought caused the breaking of apical dominance, leading to lateral shoot formation which use reserves from roots and

stems. However, all treatments were observed to have consistent dry matter percentage across the locations (Table 2). This suggests that, dry matter in cassava roots is not much influenced by environment as by genetic differences (Perez *et al.,* 2001).

3.1.2 Starch percentage

This variable showed significant variations within and across locations. Genotype, NDL 2006/487 recorded highest starch percentage content while the lowest starch percent was recorded in the genotype NDL 2006/850. The differences observed so far from one location to another could be due to the differences in rainfall distribution between those locations. Genotype, NDL 2006/487 showed consistent accumulation of starch percentages across the locations. This suggests that, this genotype is suitable for those three locations, when the intention is starch production. Starch percentage values ranged between 18.14 and 23.99 %.

3.1.3 Protein percentage

Significant variations were observed within and across locations among the studied genotypes. In this study, percentage protein content in genotypes varied significantly, ranged from 0.08 to 1.39%. This differed to some extent with results from the experiment done by Ceballos *et al.* (2006) at CIAT, where the crude protein ranged between 0.95 to 6.42%, and also FAO, (2004) reported protein in cassava roots ranging from 1 – 2%. Genotype NDL 2006/487 had the highest protein percentage means across the locations. However, the genotype had a bitter taste and hence high amount of hydrogen cyanide (Nassar and Dorea, 1982). Therefore highest values of protein percent in NDL 2006/487 may be contributed by presence of non-protein hydrogen compounds since this genotype contains high content of hydrogen cyanide. Almost all the genotypes showed wider adaptability for protein percentage mean content as performed consistently (Table 2) across the locations.

3.1.4 Root taste

Root taste was based on score scale of 1 – 2, where 1 represents sweet genotypes while 2 represents bitter genotypes. Across the locations, genotype NDL 2006/487 was found to be the most bitter, while genotype NDL 2006/741 was the sweetest. Naliendele genotype NDL 2006/487 was the most bitter. At Naliendele and Nachingwea genotype NDL 2006/741 was recorded as the sweetest (had the lowest values) (Table 1). It was generally observed that, in bitter varieties the content of protein is higher compared to sweet genotypes. This may be contributed by presence of glycosides that are present in bitter varieties, as they contain non protein nitrogen (Nassar and Dorea, 1982). In sweet genotypes the protein content was relatively low. This observation demanded carrying out a relationship between protein percentage content and root taste.

3.1.5 Relationship between protein percentage content and root taste in cassava tubers

The results in (Table 2 and Figure 1) show that, there is a negative relationship between protein percentage content and cassava root sweetness. It was observed that, bitter varieties/genotypes had higher protein percentage as compared to sweet ones. Genotypes NDL 2006/487 and NDL 200/850 had same highest value of root taste (1.89), indicating that they are the most bitter genotypes. The highest protein percentage content value was obtained on NDL 2006/487 (1.39) (Table 2). Genotypes NDL 2006/738 and NDL 2006/840, which had also high values of root taste, had higher

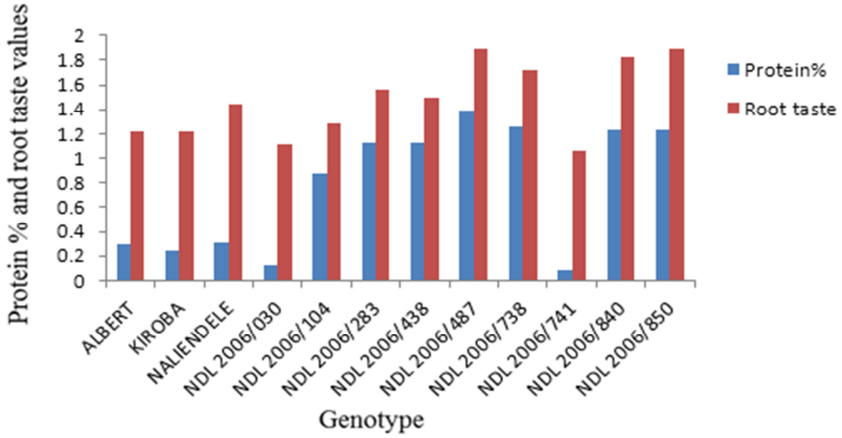

Figure 1: Relationship between cassava protein percentage content and cassava root taste

protein percentage content almost similar to NDL 2006/850 (Table 2). On the contrary, genotype NDL 2006/741 which was the sweetest (lowest value) genotype, recorded the lowest protein percentage content. NDL 2006/030 had smaller root taste value (1.11), which was not significantly different from NDL 2006/741 (1.06), which also recorded the least protein percentage content (0.12%) after NDL 2006/741 (0.08) (Table 24). Varieties Albert, Kiroba and Naliendele which showed relatively low root taste values of 1.22, 1.22 and 1.44 also revealed relatively low protein percentage contents of 0.30%, 0.24% and 0.31% respectively.

4.0 Conclusion

The twelve cassava genotypes under evaluation most had appreciable contents of dry matter and starch percentage content. On the other hand, protein percentage content was very low to medium in the tested genotypes. The low values reported in this study for protein content suggest that improvements can be made to enhance the nutritional value of this crop through varietal breeding and selection. Although this study disclosed some of the nutritional value of the twelve cassava genotypes, much more work needs to be done on determination of HCN, identifying the vitamins and other essential minerals of the cassava root and exploring their correlation.

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